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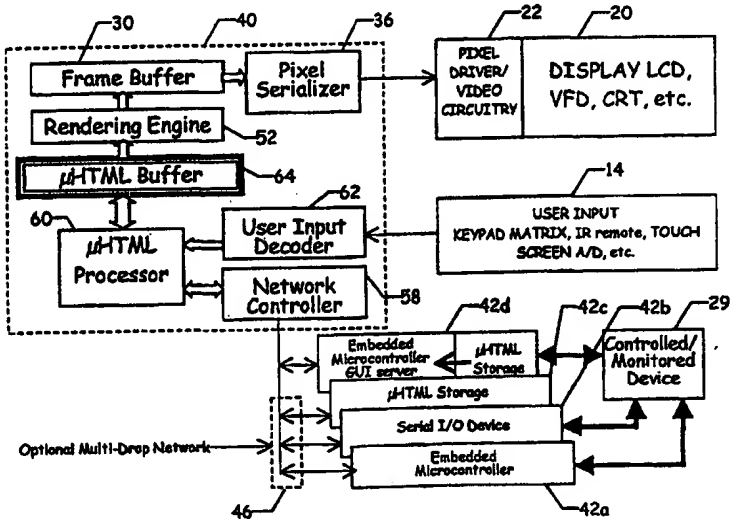

(57) Abstract

In an embedded system, for instance in a household appliance, in addition to the usual embedded microprocessor/microcontroller there is provided another processor which actually executes a user interface HTML document for accepting user input, for instance from a keypad and controlling the display device, for instance an LCD. The embedded microprocessor hosts the user interface document, responds to requests from the other processor, keeps track of changes in variables shared with the other processor, and executes the control device functionality. The other processor renders the graphical user interface to the display and interacts with the user by executing local functions to operate on the memory and i/o resources of the embedded processor as described by the user interface document served to it.

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GRAPHICAL USER INTERFACE ENGINE FOR EMBEDDED SYSTEMS

FIELD OF THE INVENTION

This invention relates to computer systems and more specifically to embedded systems, i.e. other than general purpose programmable computers.

BACKGROUND

Embedded systems are well known; this refers to microprocessors and microcontrollers (hereinafter generically referred to as microprocessors) used in devices other than general purpose computers. For instance many household appliances (such as microwave ovens) have embedded microprocessors which control operation of the appliance. The microprocessor typically accepts user input, for instance from the keypad of the microwave oven, and controls operation of the microwave oven, for instance the level of heating and duration of cooking. The embedded microprocessor also controls the device display which in a microwave oven is a small LCD (liquid crystal display). That is, the intelligence of such appliances resides in the embedded microprocessor, which interfaces to the human user. Typically this is done through firmware, i.e. computer software executed by the embedded microprocessor and stored in a memory associated with, or a part of, the microprocessor. In addition to executing the software to interact with the controlled device, the embedded

microprocessor also accepts and decodes input from the human user, for instance via the keypad, as well as provides visual feedback on the display by providing text and/or graphic information to a display controller which in turn drives the LCD panel.

As shown in the block diagram of Fig. 1, the embedded microprocessor 10 (in the drawing designated by the alternative terminology "microcontroller") is a commercially available device, for instance an 8 or 16-bit microcontroller of the type available from a number of vendors. This embedded microprocessor conventionally includes, in addition to its logic circuitry, storage such as ROM (read only memory) which holds what is called firmware 12, which is a type of computer software, and also conventional RAM (random access memory) which is not shown. Firmware 12 performs the indicated functions of application flow, device control (of the controlled device of which the embedded microprocessor is a part) reaction to user input, and the capability to draw pixels to the display controller 24 frame buffer 30.

As shown, the microprocessor 10 is coupled to a user input device 14, e.g. a keypad, an infrared remote controller such as used on television sets, or a touch screen input device. The associated controlled device (not shown) is, for instance, an appliance such as a microwave oven, washing machine, or automobile system, or a scientific instrument, or a machine tool, and is connected conventionally to microprocessor 10. It is to be appreciated that the lines connecting the blocks in

Fig. 1 represent buses, that is, parallel multiline connections. The embedded microprocessor 10 supplies input (commands) from the human user via the user input device 14 to control the controlled device and gives user indications on the display 20. Display 20 is driven via conventional pixel drivers/video circuitry 22. The user input device 14, of course, does not directly affect the controlled device, nor does it directly control the display processor 20. Instead, the embedded microprocessor 10 accepts and decodes the user input from the user input device 14, then controls the controlled device and provides information to the user on display 20. Similarly, the display device 20 does not directly display information from the user input device 14, nor the controlled device; instead it only displays information provided to it by the embedded microprocessor 10. This display takes place via the display controller 24, which is often a separate, commercially available, integrated circuit. Display controller 24 includes several well known elements which are the microcontroller (microprocessor) bus interface 28, which drives the frame buffer 30 and the associated LCD/video interface 34. As shown, the display device is for instance an LCD (liquid crystal display), VFD (vacuum fluorescent display), CRT (cathode ray tube), etc.

The Fig. 1 system is well known and has been in use for many years. It is generally suitable for a high volume production products such as household appliances where manufacturing (parts) cost is important and nonrecurring

engineering charges for developing software are relatively less important. The reason for this is that the firmware executed by the microprocessor 10 must be customized for each class of controlled device, as well as for the user input device 14 and the display 20. This requires a substantial amount of software engineering effort. However, this approach is less well adapted for non-mass-produced products such as industrial control systems, or limited production products where the software engineering costs are relatively more important than the costs of the integrated circuits. Also, even for mass produced products that are subject to frequent changes in the firmware to be executed by the embedded microprocessor 10, the costs of changing the firmware are high and the Fig. 1 approach is relatively expensive and inefficient. Hence, this approach has significant drawbacks in terms of development time and engineering cost.

SUMMARY

In accordance with this invention, a control system, for instance an embedded control system for controlling a device, operates such that the burden of accepting human user (or machine) input and providing information (output) to a human user or a machine via, e.g., a display is shifted from the embedded microprocessor to a second processor. The second processor, designated here a "hypertext" processor, is e.g. a microprocessor, microcontroller, or similar structure capable of processing a hypertext markup language document, as

explained below. The embedded control system controls and/or monitors the controlled device and is application specific, unlike for instance a personal computer which can run any application program. The display controller of Fig. 1 is effectively eliminated and its functions instead associated with the hypertext processor. Both the user (or machine) input device and the display (or other output device) are coupled to the hypertext processor and not to the embedded microprocessor. The hypertext processor is a second, e.g., microprocessor which may be on a chip separate from the embedded microprocessor.

The hypertext processor determines what operations to take upon receipt of, e.g., user input, for instance from a connected keypad. The hypertext processor performs actions described in the hypertext markup language document and commands the embedded microprocessor to act on the controlled device and to update its internal shared variables. The hypertext processor also updates the display as a function of the shared variables internal to the embedded microprocessor. The user interface software (code) is not resident in the hypertext processor, nor is it executed/interpreted by the embedded microprocessor. Instead, a (hypertext) document describing the user interface is external to the hypertext processor, and resident in the memory space of the embedded microcontroller or in a serial memory device (i.e. serial EEPROM, FLASH ROM, smart card, etc.). This hypertext document describing the user interface is provided ("served") to the hypertext processor at the request of the hypertext processor.

Thus the user interface is actually executed by the hypertext processor even though it does not permanently reside there.

In one embodiment, the user interface document is encoded in a particular hypertext markup language (HTML) called here µHTML. The generic name "Hypertext Markup Language" refers to:

> Hypertext - A method for providing links within and between documents; popularized by multimedia authoring systems which used the hypertext concept to link the content of a text document to other documents encoded in certain multimedia formats.
>
> Markup Language - A method for embedding special control codes (TAGS) that describe the structure as well as the behavior of a document.

Like conventional HTML, µHTML files ("documents") contain both control information (markup tags) and content (ASCII text), which together describe the appearance and content of a user interface. In addition, both markup languages provide capability to reference resources external to the document. Compared to conventional HTML, µHTML is smaller, easier to interpret, and defines a special library of GUI (graphical user interface) objects, data processing objects suitable for pipelining, and other system utilities common to embedded systems software. One key feature of µHTML is its ability to describe the interface to resources distributed among networked embedded subsystems and to link the data of these resources to the functions of a host processor.

In order to make µHTML easy to parse, it is headed by a directory of pointers to each tag. To make it compact, each tag is represented by a single byte (hereinafter referred to as an opcode). Following each opcode is a unique set of binary

properties data, such as X-Y coordinate information, pointers to other resources, and other properties. There is a unique opcode for each object in the GUI object library. These objects are, e.g., push buttons, pop-up lists, and other sorts of visual (or aural) indicators. There are also opcodes for objects that contain methods to process or redirect data to and from other objects or external resources, e.g., an object referencing a variable from "external resource 0" may sample the variable data every 100 mS, and route the results to another object referencing a variable from "external resource 1". Each library object opcode is followed immediately by a data structure unique to the object. The data contained in the data structure is specific to the instance of the library object. In this way, the memory allocated for each instance of all used objects is statically allocated in the memory buffering the μHTML document. When external resources are referenced, a data structure is provided to describe the format of the messages required to provide access to the external resource. For instance, to read a variable associated with an external device, the data structure describes a "Get" command and a "Return" response. Typically the Get command contains an identification to some external device and an index into a lookup table on the external device that provides references to variables, functions or files. In addition to the external device identification and lookup table index, the Return response also contains the data requested.

In one embodiment this user interface hypertext document

is developed using conventional internet web page development tools of the type commercially available; this is not limiting. User interface objects are simulated in one embodiment with JAVA applets that correspond to objects in the GUI object library. The simulated GUI objects are referenced from within the conventional HTML document by using the same standard tags used to reference any conventional JAVA applet. Standard HTML tags are also used to format the display content and to point to resources resident to devices external to the hypertext processor.

The user interface document can then be viewed on a conventional web browser, for system development purposes. (Of course this has little to do with the actual user operation of the controlled device but is part of its user interface design and development.) This HTML/JAVA web page can then be converted (pre-compiled) to a more compact μHTML format by a compiler designed specifically to: (1) remove the conventional HTML tags and replace them with a corresponding μHTML opcode; (2) convert the attributes strings of the HTML tags to a binary structure appropriate for the μHTML opcode; (3) replace references to all JAVA applets and parameters with a corresponding opcode and object data; (4) reformat and add additional data to simplify parsing and execution by the hypertext processor, and (5) resolve references to resources external to the hypertext processor (i.e. executable code or variable data resident to an external embedded microprocessor, storage in an external serial memory device, I/O functions of

an external serial I/O device, etc.). This is only illustrative of development of a system in accordance with this invention.

Moreover, the present invention is directed to more than a user interface processor. It is additionally directed to use of a hypertext markup language to provide program flow and structure while linking together resources distributed among embedded subsystems, even if the subsystems do not have user interfaces. That is, the invention more broadly contemplates a dedicated processor programmed with a hypertext markup language rather than with conventional application code.

BRIEF DESCRIPTION OF THE FIGURES

Fig. 1 shows a prior art embedded control system for a controlled device.

Fig. 2 shows an embedded control system in accordance with this invention.

Fig. 3 shows a more detailed diagram of the markup language processor of Fig. 2.

Fig. 4 shows an HTML file and associated request handler in accordance with the invention.

Fig. 5 shows the relationship between the HTML source file of Fig. 4 and a version compiled to μHTML.

DETAILED DESCRIPTION

Fig. 2 shows a block diagram of a control system for a controlled device in accordance with this invention. Blocks

similar to those of Fig. 1 have identical reference numbers. In Fig. 2, the display controller 24 of Fig. 1 is replaced by a second hypertext processor 40 which may be (not necessarily) a single integrated circuit and which is an intelligent device, unlike the display controller 24. Thus in the Fig. 2 structure there are two intelligent devices (processors), one of which is the hypertext processor 40 and the second of which is, e.g., the embedded microprocessor (or other device) of which several are shown labeled 42a etc. The hypertext processor 40 interfaces both to the user input device 14 and to the display elements 20, 22. Any networked device such as 42c or 42d that contains storage for the user interface (hypertext) document may serve (provide) the user interface document to the markup language processor 40. Any networked I/O device such as 42a, 42b, or 42d that acts upon a controlled or monitored device 29 may have resources that are referenced by the user interface document(s). "Networked" here refers to device connectivity using standard protocols. It includes both "intra-product" networking (connecting several devices within one enclosure) and "inter-product" networking (connecting devices each in its own enclosure.)

Fig. 2 shows different types of devices optionally connected by a conventional network 46 to markup processor 40. These connected devices include embedded microcontroller 42a, serial I/O (input/output) device 42b, μHTML storage device 42c, and embedded microcontroller GUI server 42d including its own μHTML storage. Of course other connection arrangements are

possible with any number or combination of devices or networks connected to the markup language processor 40 as long as there is at least one device, e.g., 42c capable of storing the μHTML document(s). Also, because a single μHTML document may contain links to the resources of different devices on the network, it is not necessary for every device on network 46 to contain storage for μHTML documents.

Although Fig. 2 shows only one controlled device 29 connected to a plurality of devices, there may be one or more such controlled devices that may be controlled (or monitored) by one or more of the networked I/O devices 42a, etc. In addition, the networked I/O 42a, etc. devices may or may not be located in the same physical enclosure. For example, the components of a microwave oven may be networked in the same physical enclosure. However, the components of a home entertainment system (e.g., surround sound receiver/amplifier, VCR, CD/DVD player) may all be networked to a hypertext processor, e.g. in a television set, but each housed in its own physical enclosures.

Also, while the various blocks 30, 40, 20, 22, and 42a, 42b etc. of Fig. 2 in one embodiment are separate integrated circuits, the partitioning amongst the various integrated circuits may be otherwise, for instance, all of the Fig. 2 system may be on a single integrated circuit with the possible exception of the user input device 14, controlled device 29, and display 20. The partitioning of the depicted blocks amongst various integrated circuits is not critical to this

invention.

The following describes each functional block of the hypertext processor 40 of Fig. 2:

Network controller 58 formats and transmits all bytes of data queued by the μHTML processor 60 via the network 46. It also decodes any data received from the network 46 and places it in a queue to be processed by the μHTML processor 60.

User input decoder 62 detects and decodes input from user input device 14 which is, e.g., a keypad, touch screen, voice command decoder or IR (infrared) remote device. Decoder 62 places data describing a user input event into a queue to be processed by the μHTML processor 60.

μHTML processor 60 operates on data stored in μHTML buffer 64 to reflect events queued from the user input decoder 62 and network controller 58. Processor 60 is also responsible for generating and queuing events for the network controller 58 in response to system or user events that are linked to such events by the data in the μHTML buffer 64.

μHTML buffer 64 is RAM (random access memory) storage for a complete μHTML document describing all objects to be rendered to the display device 20. Each object contained in the μHTML document may also contain references to other network resources. Buffer 64 is only written to and modified by the μHTML processor 60 in response to user input events, system events or events generated in response to network messages. It is read by both the rendering engine 52 and the μHTML processor 60. μHTML buffer 64 is a section of RAM 72 accessible only by

the microprocessor 68(see Fig. 3).

The rendering engine 52 only reads the graphic information for each UI object as required to properly draw the user interface to the frame buffer 30. The μHTML processor 60 reads the information required to generate system or network events in response to other events related to each UI object.

Rendering engine 52 draws all displayable user interface objects to the frame buffer 30 as described by the data stored in the μHTML buffer 64. It refreshes each UI object when marked as "dirty" in the μHTML buffer 64 by the μHTML processor 60. Rendering engine 52 is firmware executed by microprocessor 68 and stored in ROM 70(see Fig. 3). Each μHTML object contains code to render all views of the object.

Frame buffer 30 is RAM storage that contains the data for each pixel of the entire displayed page. It is written to by the rendering engine 52 as it draws the user interface on display 20. It is read from by the pixel serializer 36 as it converts the pixel information to signals appropriate to drive the physical display 20. Frame buffer 30 of Fig. 2 is a section of RAM 72 (see Fig. 3) accessible by microprocessor 68 (see Fig. 3) and the pixel serializer 36.

Pixel serializer 36 generates a continuous pixel stream in a format compatible with a specific commercially available physical display 20. As an example, when interfacing to an LCD panel (display 20), the pixel serializer collects and formats each line of pixel data from the frame buffer 30 and synchronizes it with the conventional display driver pixel

clock, frame pulse and line pulse signals. The pixel clock signal clocks the pixel data into the display drivers' internal shift register. The line pulse signal indicates the end of a display line while the frame pulse signal marks the first line of the displayed page.

The Fig. 2 structure advantageously allows use of commercially available internet web page authoring tools (such as HTML) to use "drag and drop" graphic user interface authoring for development of microprocessor based embedded systems. Also, it allows a simple and consistent serial interface via network controller 58 to devices 42a, 42b, etc. regardless of the configuration of the display 20. In other words, the intelligence for control of the display 20 is provided in the processor 40 and need not be coded in the embedded microprocessor 42a software.

This eliminates the conventional programming, for example in assembler or C, required to implement graphical user interface objects that are linked to the variables and functions of the embedded microprocessor 10 such as is required in the prior art system of Fig. 1. It also allows development of the program flow by the non-software engineers who typically specify the application for the controlled device 29 of Fig. 2 and thereby understand the application and user interaction, but not perhaps firmware programming. This allows quicker and more accurate program development while freeing up the experienced firmware developers to concentrate on the technical program and also yielding better partitioning of a development

project into smaller more manageable chunks that may be developed in parallel.

Fig. 3 shows a "hardware" oriented block diagram of the hypertext processor 40 of Fig. 2. Processor 40 connects to one of the embedded devices 42a etc. In this case, the protocol engine 58 of Fig. 2 is shown as queued serial interface 58' which is, for instance, a UART/SPI/I^2C interface. These are examples of industry standard interfaces suitable for the "intra-product" networking described above. SPI (Serial Peripheral Interface) is a popular synchronous serial communication scheme for networking of integrated circuits contained in embedded systems. It was designed by Motorola and popularized by MAXIM, Harris, SanDisk, and others. It is supported by many microcontrollers and serial I/O devices such as A/D and D/A converters, solenoid drivers, digital potentiometers, real time clocks, EEPROM, FLASH ROM, among many others. I^2C-Bus (Inter-IC Bus) is another popular synchronous serial network architecture popularized by Philips and is simpler, but slower than SPI. Like SPI, many serial I/O and storage functions are available. However, many more consumer product functions are available, i.e. television and stereo building blocks. Examples of suitable interfaces for protocol engine 58' for "interproduct" networks are IEEE-1394, USB, or Ethernet. In conjunction with appropriate firmware executed by the microprocessor 68 and stored in ROM 70 protocol engine 58 services interrupts generated by the connected devices and manages queues.

The user input decoder 62 is shown in Fig. 3 as a keypad scan decoder 62' which connects to a keypad 14. In conjunction with appropriate firmware executed by the microprocessor 68 and stored in ROM (read only memory) 70, decoder 62 services interrupts generated by the connected devices and manages queues. The remaining blocks in Fig. 3 support the other functions of markup language processor 40 of Fig. 2. This is accomplished in terms of circuitry by microprocessor "core" (this is the microprocessor without the supporting memory, etc.) 68 which in turn is connected to a standard bus 76 which interfaces as shown to the other blocks within processor 40. Typically, the entire processor 40 of Fig. 3 would be a single integrated circuit.

μHTML Processor 60 of Fig. 2 in Fig. 3 is firmware executed by microprocessor 68 and stored in ROM 70. In addition to routines to service interrupts, handle events and manage RAM 72 based queues 78 and buffers, this also contains a library of routines that operate on and according to the specific data structures of each μHTML object. These objects may contain, but are not limited to, user interface objects, data processing objects and operating system objects. The data for each instance of an object is contained in the μHTML document buffered in the RAM 72 area called the μHTML buffer 64. Each μHTML object in the library 84 in ROM 70 contains code to (1) access and modify the data defining the instance of the object (from μHTML buffer 64), (2) render all views of the object to RAM frame buffer 30, (3) respond to events related to

the object and (4) queue messages to be sent to other network resources.

The structures in Fig. 3 include (in ROM 70) main program storage 88 and event handlers 90 and (in RAM 72) stack 96 and heap 98. Pixel serializer 36 of Fig. 2 is depicted as hardware (circuitry) in Fig. 3.

The block diagrams of Figs. 2 and 3 are descriptive of a range of structures which may be implemented in various combinations of dedicated hardware (circuitry) and software (computer code) executed by various types of processors. The particular partitioning between hardware and software disclosed herein is not intended to be limiting.

Fig. 4 illustrates an example of an application used in accordance with this invention. Specifically, the central portion of Fig. 4, which is the text 86, is an HTML file, that is a hypertext markup language document which links display items of an LCD display 88 to resources of an embedded microprocessor. The various lines of text in 86 contain either: (1) text to be displayed such as "Two Variables" or "LED 0", or (2) markup tags (enclosed between < and >) to reference GUI object library components and link them to resources external to the HTML document and markup language processor. In this example, the embedded microprocessor resources are accessed through the embedded microprocessor software program 92.

The embedded microprocessor resident resources accessed by program 92 are: two variables in this case containing the

values 123 and 321, and two functions that in this case turn on an LED and turn off an LED attached to the embedded microprocessor. The variables are displayed via IntField objects and accessed by sending the commands in the <PARAM Name = "Send"...> tags. Upon receiving the command to GET a variable, the embedded processor executes the code in 92 to lookup the variable and send the value back via the ackClient routine. The IntField object of the markup language processors GUI Object library parses the response as per the <PARAM Name="Return"...> tag to isolate, format and render the value to the LCD's frame buffer.

Likewise the functions referenced by the <PARAM Name="Send"...> are invoked when the user activates the buttons rendered by the FunctBtn objects.

Associated with this document 86 is embedded request handler 92, shown in the right hand portion of Fig. 4 with lines relating it to the markup in document 86. This handler 92 is resident in an embedded microprocessor such as, with reference to Fig. 2, 42a or 42d to provide access to the resources requested via the network. This code in 92 may be implemented in hardware for example in serial memory devices such as, with reference to Fig. 2, 42c or in serial I/O devices such as 42b. The "client" in the code 92 is a reference to the markup language processor 40. Thus, while the data described by document 86 is actually interpreted by the markup language processor 40, the code 92 is actually executed by the embedded microprocessor 42a in conjunction therewith.

Fig. 5 shows a repetition of the HTML source file (left side) 86 of Fig. 4 with a compiled μHTML version of same (right side). This compiled μHTML version is much more compact; the lines relate the source file code to its compiled version. In addition, the μHTML is easier to interpret at runtime, because things such as string lengths, tag offsets, X-Y coordinates are computed by the compiler and built into the structure of the document. Of course there is no requirement to use HTML or μHTML or to compile same, however, this provides efficiencies in carrying out one embodiment of the present invention.

Alternatives to use of the μHTML disclosed here are other forms of text documents with control codes used to access resources located elsewhere. Examples of other markup languages are compact HTML, and HDML. Even the old UNIX "troff" is a markup language which was originally designed for page layout.

Memory devices (such as 42c) (Fig. 2) external to the processor 40 are thereby responsible for "hosting" the μHTML and other files. Whether the external device is another microprocessor 42d, or simply a serial memory device 42c, it reacts to requests from the processor 40 to read or write files. In addition devices 42a etc. connected to the processor 40 may also support requests to read/write variables, invoke functions and provide state information while performing the normal I/O device functionality.

The embedded memory device 42c is thereby responsible for

"hosting" the μHTML and other files. It responds to requests from the hypertext processor and keeps track of changes to variables in use by the hypertext processor and executes the controlled device functionality. The hypertext processor is responsible for rendering the graphical user interface to the display. The hypertext processor is also responsible for responding to user input from the user input device by updating display graphics and communicating with external devices to request changes to the values of external variables and to invoke external functions as described by the μHTML document. The hypertext processor is also responsible for responding to changes in the embedded microprocessor variables by updating the display device graphics. Typical requests to the embedded microprocessor by the hypertext processor are: open connection; get file (for instance a μHTML file, an image graphic file or a script); call up functions; get a value of the variable; send value of the variables and obtain status of the embedded microprocessor. "Script" refers here to files that contain code to be executed by the microprocessor portion of the hypertext processor.

This disclosure is illustrative and not limiting; further modifications will be apparent to one skilled in the art in light of this disclosure and are intended to fall within the scope of the appended claims.

CLAIMS:

What is claimed:

1. An embedded control system to control or monitor an associated device, wherein the associated device includes an input/output portion, the embedded control system comprising:

a processor coupled via input/output circuitry to the input/output portion for controlling operation of the associated device; and

a memory associated with the processor, the memory storing one or more documents linked to each other, but not containing executable code, to describe methods to control or monitor the associated device by linking functions executable by and local to the processor with descriptions of the interactions required to access the input/output circuitry;

wherein the processor receives the stored document from the memory and performs the control or monitor methods of the stored documents by executing the functions referenced by the stored documents to operate on the input/output circuitry linked to the functions by the stored documents, thereby to control or monitor operation of the input/output portion.

2. The system of Claim 1, further including a second processor coupled between the processor and the input/output circuitry, the second processor including internal resources to facilitate controlling or accessing the

input/output circuitry;

wherein the internal resources are linked to functions executable by the first processor via links from the stored documents, thereby to control or monitor operation of the input/output portion.

3. The system of Claim 1, wherein the processor includes a memory to store a copy of the stored document while it executes the linked functions; and the stored document contains an initialized data structure representing the variable data for each function being linked thereto, thereby allocating space in local memory of the processor for each instance of the functions linked from the stored document.

4. The system of Claim 1, wherein the input/output portion includes driver circuitry and a display coupled to the driver circuitry.

5. The system of Claim 1, further comprising an additional processor with an associated memory coupled to the processor.

6. The system of Claim 5, wherein the coupling is via a network.

7. The system of Claim 6, wherein the network is one of an inter-product or an intra-product network.

8. The system of Claim 1, wherein the functions executable by and local to the processor are objects for controlling or monitoring the input/output circuitry coupled to the input/output portion, thereby to control functions of the associated device.

9. The system of Claim 8, wherein the objects include graphical user interface objects.

10. The system of Claim 1, further including stored documents that do not contain executable code, but do contain links to other stored documents that do contain executable code.

11. The system of Claim 1, wherein the input/output portion includes user input decoding circuitry coupled to a user input device.

12. The system of Claim 1, wherein the stored document is a hypertext markup language document.

13. The system of Claim 1, wherein the stored document is compiled from a hypertext markup language document by partitioning the interpretation of the document into a compilation time phase and a run time phase, wherein the compilation phase produces an intermediate document to be

stored in the memory and executed by the processor during the run time phase, thereby reducing the burden on the processor for executing the stored document.

14. The system of Claim 2, wherein the second processor is housed in an enclosure separate from an enclosure housing the processor.

15. A method of controlling a device having an associated processor and an input/output portion, comprising the acts of:

storing a document which describes methods to control or monitor the associated device by linking functions executable by and local to the processor with descriptions of the interactions required to access the input/output portion;

upon a request, transmitting at least a portion of the stored document to the processor; and

executing the transmitted document at the processor, thereby to control operation of the input/output portion.

16. The method of Claim 15, wherein the document is a hypertext markup language document.

17. A method of implementing a user interface for an embedded system with a controlled/monitored device and an associated processor and an input/output portion, comprising the acts of:

developing a document which describes methods to control or monitor the device and interact with a user of the device by linking functions executable by and local to the processor with descriptions of the interactions required to access the input/output portion;

storing the document;

upon a request, transmitting at least a portion of the stored document to the processor; and

executing the transmitted document at the processor, thereby to allow the user to interact with the device.

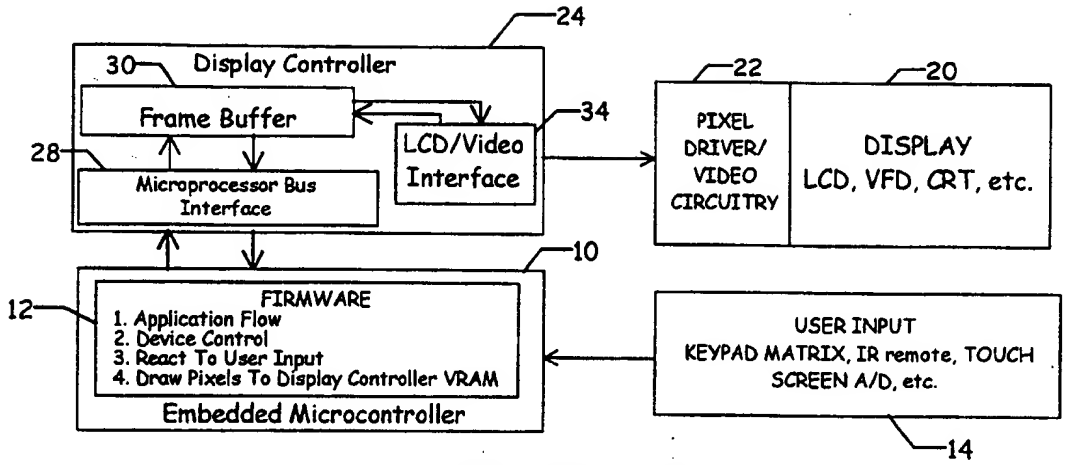

FIG. 1. (Prior Art)

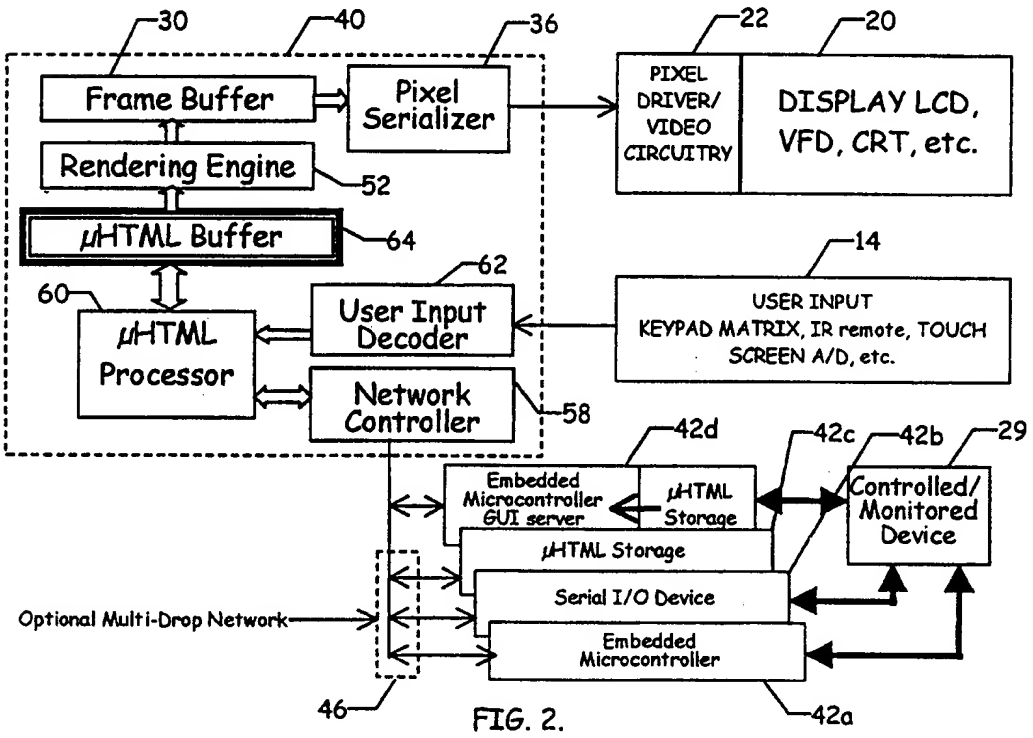

FIG. 2.

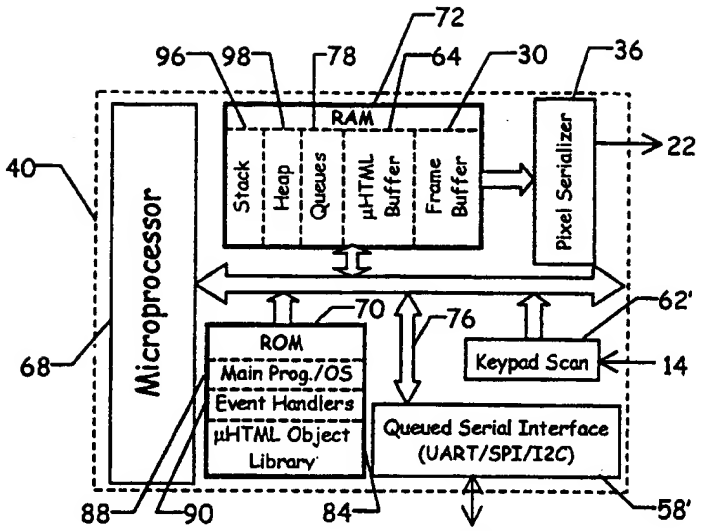
72
96
98
78
64
30
36
RAM
Stack
Heap
Queues
µHTML Buffer
Frame Buffer
Pixel Serializer
22
40
Microprocessor
62'
70
76
ROM
Main Prog./OS
Event Handlers
µHTML Object Library
Keypad Scan
14
68
Queued Serial Interface (UART/SPI/I2C)
88
90
84
58'
42a

FIG. 3.

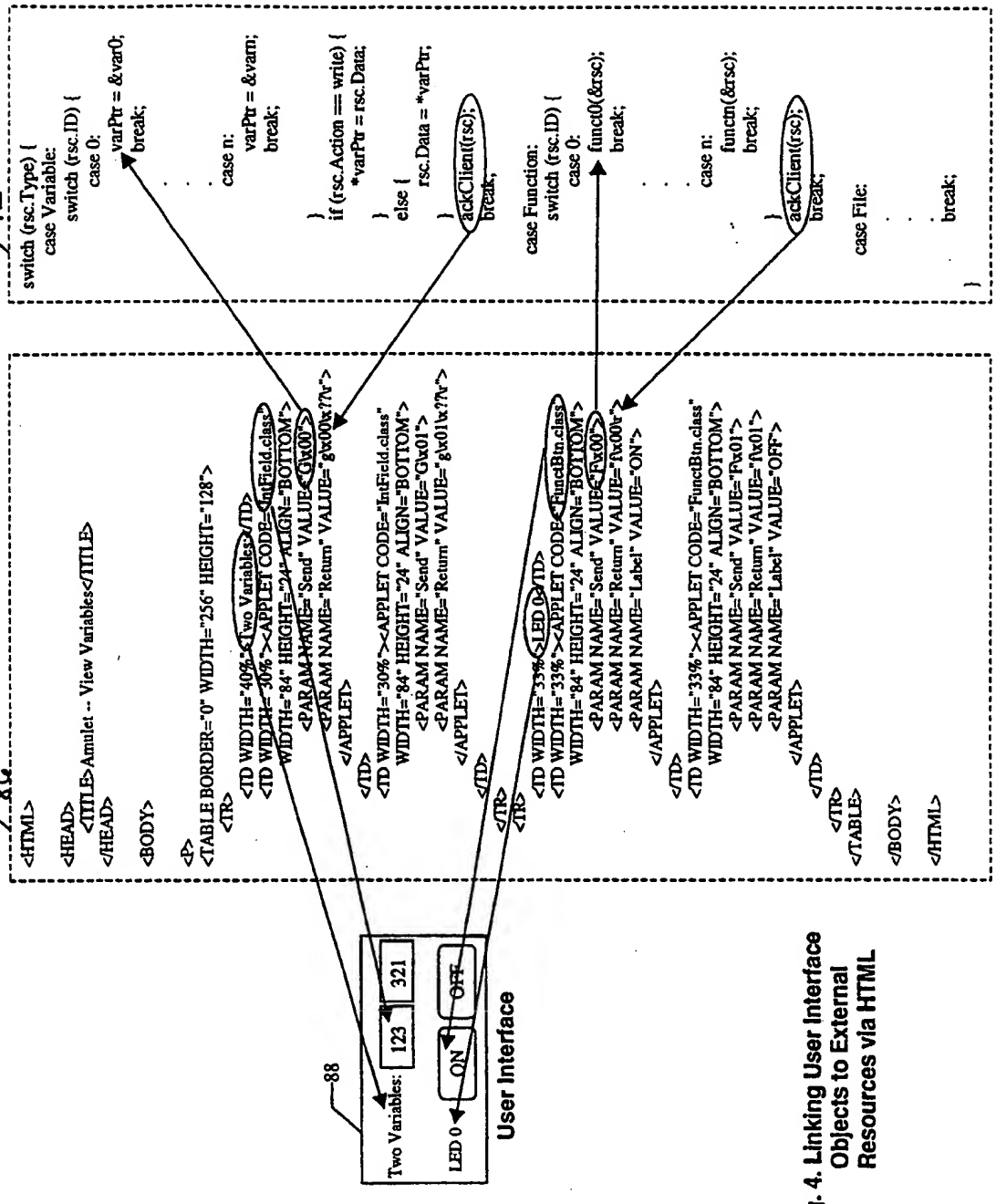

Fig. 4. Linking User Interface Objects to External Resources via HTML

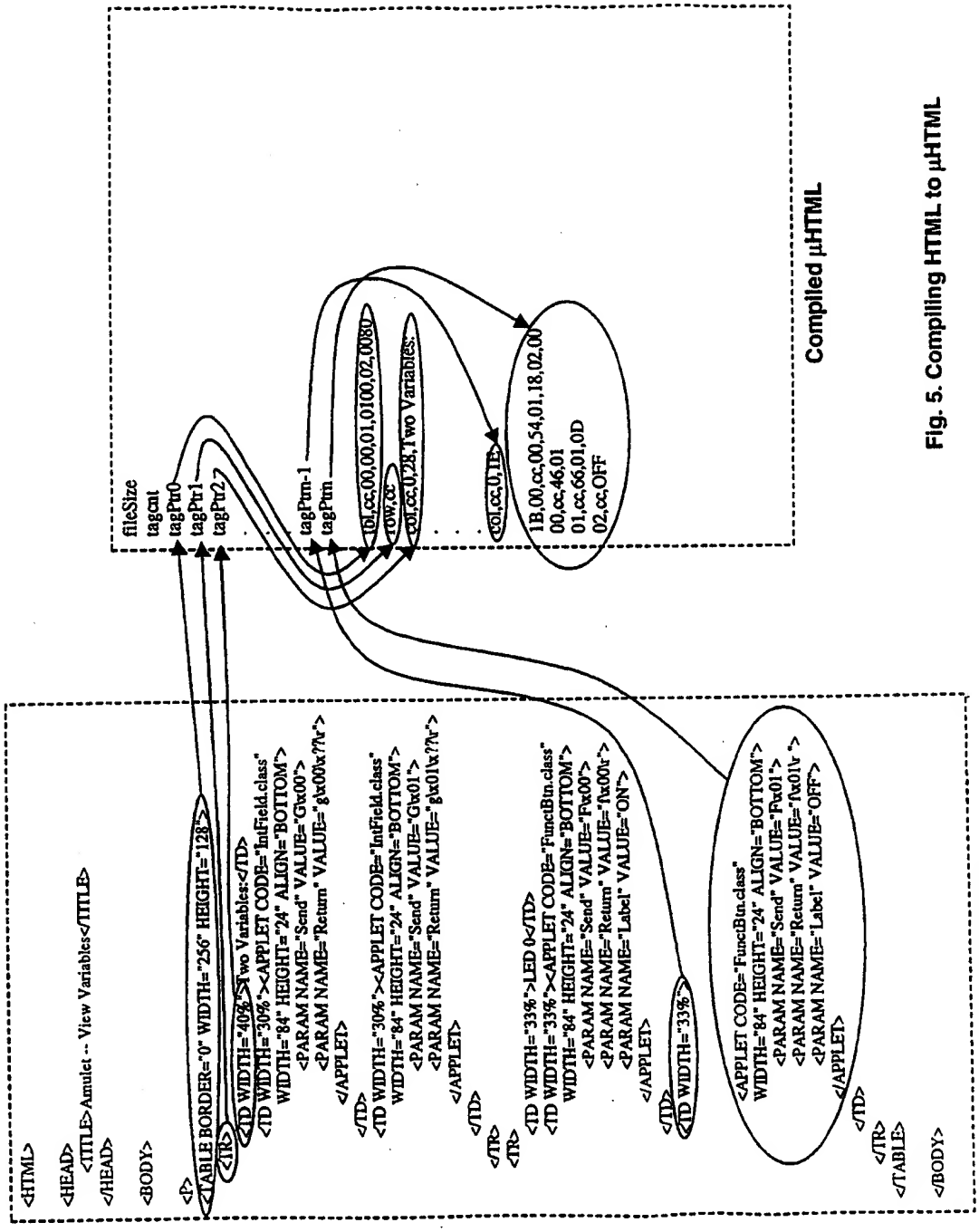

Fig. 5. Compiling HTML to µHTML